

APPENDIX

1. An integrated circuit comprising:
 - a silicon substrate;
 - an insulating layer formed on the silicon substrate wherein the insulating layer has an opening that extends from an upper surface of the insulating layer to an upper surface of the substrate so as to expose the upper surface of the substrate;
 - a metal layer formed in the opening wherein a first portion of the metal layer is formed on the exposed upper surface of the substrate and reacts with silicon in the substrate to form metal silicide, wherein a second portion of the metal layer does not contact the substrate and remains unreacted; and
 - a metal silicide adhesion layer formed on an upper surface of the second portion of the metal layer, wherein the metal silicide adhesion layer adheres the second portion of the metal layer to a metal nitride layer that is subsequently formed on the first and second portions of the metal layer.
2. The integrated circuit of Claim 1, wherein the metal layer comprises titanium.
3. The integrated circuit of Claim 2, wherein the metal nitride layer comprises titanium nitride.
4. The integrated circuit of Claim 3, wherein the metal silicide adhesion layer comprises titanium silicide.
5. (Canceled)
6. The integrated circuit of Claim 4, wherein the metal silicide adhesion layer is approximately 50-150 Å thick.
7. The integrated circuit of Claim 1 wherein the opening is a contact opening.
8. The integrated circuit of Claim 1, wherein the contact opening has an aspect ratio of at least 10:1.
9. The integrated circuit of Claim 8, wherein the exposed upper surface of the substrate comprises a junction region.
10. The integrated circuit of Claim 9 further comprising a contact fill formed on an upper surface of the titanium nitride layer wherein the contact fill substantially fills the contact opening.

11. The integrated circuit of Claim 10 wherein the contact fill comprises titanium nitride.

12. The integrated circuit of Claim 11, wherein the titanium nitride contact fill comprises TiCl_4 based titanium nitride.

13. The integrated circuit of Claim 10 wherein the contact fill comprises tungsten.

14. A high aspect ratio contact structure formed over a junction region in a silicon substrate, comprising:

an insulating layer wherein the insulating layer defines a contact opening wherein the contact opening is formed over the junction region of the substrate and exposes a portion of the substrate;

a titanium layer formed in and adjacent the contact opening, wherein a first portion of the titanium layer is formed on the insulating layer and a second portion of the titanium layer is formed on the exposed portion of the substrate, wherein at least a portion of the second portion of the titanium layer contacts the exposed substrate and reacts with the silicon in the substrate to form titanium nitride, wherein the first portion of the titanium layer does not contact the substrate;

a titanium silicide adhesion layer formed on an upper surface of the first and second portions of the titanium layer and

a titanium nitride contact fill formed in and adjacent the opening, wherein the titanium nitride is formed on an upper surface of the titanium silicide adhesion layer, wherein the titanium nitride contact fill is adhered to the first portion of the titanium layer by the titanium silicide adhesion layer.

15. The contact structure of Claim 14, wherein the contact opening has an aspect ratio of at least 10:1.

16. The contact structure of Claim 14, wherein the titanium nitride contact fill comprises a TiCl_4 based titanium nitride.

17. The contact structure of Claim 14, wherein the insulating layer comprises BPSG.

18. The contact structure of Claim 14, wherein the titanium silicide adhesion layer is approximately 50-150Å thick.

19. The contact structure of Claim 14, wherein the titanium silicide adhesion layer comprises a titanium rich layer interspersed with titanium silicide.

20. The contact structure of Claim 14, wherein the titanium silicide adhesion layer comprises less chlorine than the titanium layer.

21. A method of forming a contact structure on a silicon substrate, comprising:
forming an insulating layer on an upper surface of the substrate;
forming an opening in the insulating layer, wherein the opening extends from an upper surface of the insulating layer to the upper surface of the substrate;
forming a titanium layer in and adjacent the opening, wherein a first portion of the titanium layer is formed on the upper surface of the substrate and a second portion of the titanium layer is formed on the upper surface of the insulating layer adjacent the opening;
reacting the first portion of the titanium layer with silicon in the substrate so as to form a titanium silicide layer adjacent the upper surface of the substrate;
forming a titanium silicide adhesion layer over the second portion of the titanium layer; and
forming a titanium nitride layer on an upper surface of the titanium silicide adhesion layer, wherein the titanium silicide adhesion layer bonds the titanium nitride layer to the second portion of the titanium layer.

22. The method of Claim 21, wherein forming a titanium layer in and adjacent the opening comprises depositing a titanium layer using a PECVD process.

23. The method of Claim 22, wherein depositing the titanium layer comprises using a gas mixture comprised of TiCl_4 , Ar, H_2 , and He.

24. The method of Claim 23, wherein depositing the titanium layer comprises using a reaction gas temperature of about 650 °C, RF power of about 400 W, and pressure of about 4 Torr.

25. The method of Claim 21, wherein reacting the first portion of the titanium layer with silicon comprises using an annealing reaction.

26. The method of Claim 21, wherein forming a titanium silicide adhesion layer comprises depositing a layer of titanium silicide using a PECVD process.

27. The method of Claim 26, wherein depositing the titanium silicide adhesion layer comprises using a gas mixture comprising TiCl_4 , Ar, H_2 , He, and SiH_4 .

28. The method of Claim 27, wherein depositing the titanium silicide adhesion layer comprises adding about 10 sccm SiH_4 to the gas mixture at about 400 W.

29. The method of Claim 28, wherein depositing the titanium silicide adhesion layer comprises using reaction gas temperature of about 650 °C, RF 400W, and pressure of about 4 Torr.

30. The method of Claim 21, wherein forming a titanium nitride layer comprises depositing a titanium nitride layer using a thermal CVD process from TiCl_4 and NH_3 precursors.

31. The method of Claim 30, wherein depositing the titanium nitride layer comprises using a process temperature of about 600 °C.

32. The method of Claim 21, further comprising forming a contact fill in opening.

33. The method of Claim 33, wherein forming the contact fill comprises depositing a metal in the opening.

34. The method of Claim 34, wherein forming the contact fill in the opening comprises using a chemical vapor deposition process.

35. The method of Claim 35, wherein forming the contact fill in the opening comprises depositing a titanium nitride contact fill, wherein the titanium nitride fills substantially the entire opening.

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